Chapter 8
Instrumentation Maintenance

8-1. Introduction

Proper design and installation of instruments provides a reliable and functional system. With usage and the passage of time the instrumentation system must be maintained to continue its reliable and useful function. This chapter deals with maintenance including recalibration of instrumentation systems during service life. Maintenance and recalibration of general instrument types and most commonly used instruments are discussed. The basic maintenance and recalibration concepts discussed for these types of instruments can be applied to all other types of instruments.

8-2. Importance of Maintenance and Recalibration

Careful attention to factory calibration, pre-installation acceptance tests, installation, and post-installation acceptance tests should ensure that instrumentation systems are operationally satisfactory to monitor the performance of the dam or levee. However, to ensure that the systems remain in a satisfactory operating condition during their service life, regular maintenance and recalibration are necessary. Lack of regular maintenance and recalibration will result in invalid data which can lead to incorrect conclusions. Lack of maintenance will also jeopardize the functioning of the system, and risk the loss of individual instruments, which in many cases cannot be replaced.

a. General concepts. Maintenance is the responsibility of the owning agency. The agency's maintenance requirements and procedures should be planned during the design of the instrumentation system and outlined in the project Operation and Maintenance (O&M) Manual. Planning for maintenance and recalibration is discussed in Chapter 3. Although it may not be practicable to develop a project-specific maintenance manual because of cost, the O&M Manual should include as many guidelines as possible, and should include the instrument manufacturer's instruction manuals. Maintenance procedures should be based on the manufacturer's instruction manual and on the project-specific site conditions, and include such needs as preventative maintenance program schedules, troubleshooting, cleaning, drying, lubricating, battery servicing, disassembly, and repair and replacement instructions for each type of instrument.

b. Maintenance contracts. Maintenance and recalibration are best accomplished by the owning agency's personnel, and the first option should be to use District personnel before contracting out services. However, instrumentation systems and components usually have limited warranty periods, and a maintenance contract with the manufacturer could be a wise investment. Government contracting procedures, specifications, and guidance should be followed for any contractual agreements. Any contractual agreements for regular maintenance and recalibration should define scope of work, requirements, procedures, schedules, contractor qualifications, experience, and personnel qualifications and experience.

c. Personnel responsible for maintenance and recalibration. Personnel should be reliable, dedicated, and motivated people who will pay attention to detail. They should have a background in the fundamentals of geotechnical engineering and have mechanical and electrical ability. They should be able to understand how the dam or levee functions and how the instruments function. The maintenance and recalibration checks of an instrumentation system during service life are best supervised by or accomplished by the data collection personnel, who are in the position to notice potential problems and to observe malfunctions, deterioration, or damage. Qualifications for data collection personnel are discussed in Chapter 3. They should be trained to perform scheduled preventative maintenance and to initiate corrective action, repair, or replacement without delay. Their training should also include all personal safety training required for conditions, equipment, and materials related to the performance of their duties. If maintenance, recalibration checks, or corrective action are not routine or are beyond the capability of data collection personnel, the data collection personnel should communicate this to the office responsible for inspection and analysis, so that arrangements can be made for action to be taken by the instrumentation program manager.

d. Service history. A service history record of maintenance, recalibration, repair, and replacement of the components of the system should be kept and communicated to the personnel responsible for analysis. The record should include dates, observations, what the problems were, what was done, how it was accomplished, who was involved, and anything else that will help to understand or interpret the instrumentation data. A service history establishes the general behavior that is characteristic of the system and suggests what frequency of maintenance is needed. The service history also facilitates the transfer of responsibility due to turnover in personnel.

e. Spare parts. Appropriate spare parts and interchangeable components should be available for replacing failed or questionable components without interrupting system operation during service life. An inventory of spare parts and instruments should be available and revised as necessary. Spare readout units should also be available in case of malfunction of primary readout units.

8-3. Recalibration During Service Life

After instruments are in service, they will require regular recalibration to maintain proper operational characteristics. However, some instruments such as an embedded transducer cannot be recalibrated. As a general rule recalibration should be performed on a well-defined schedule. Formal schedules and reporting requirements for routine recalibration are necessary to ensure that the readings obtained are reliable. Routine recalibration of instrumentation system components is best performed by personnel responsible for data collection, and coordinated with the data analyses personnel. Instrumentation data will have to be interpreted for indications that recalibration is needed. The data should be watched for abrupt reading changes for no apparent reason. If the data are showing a long-term change, it should be verified whether or not the change is actual or is due to a malfunctioning instrument, which may need to be recalibrated. Procedures for recalibration during service life should be included in the O&M Manual. Components of most instrumentation systems can be classified into three groups: portable readout units, retrievable components at field terminals, and embedded components. Maintenance of these three components are discussed below. Other instruments that do not fit into the three-component classification are discussed later in this chapter.

a. Portable readout units. Portable readout units generally are vulnerable to mishandling and subject to calibration changes. Some readout units can be checked and recalibrated by following procedures provided by the manufacturers. If they cannot be checked in this way, they should be sent to the manufacturer for calibration, adjustment, or repair. Local commercial calibration companies that use equipment traceable to the National Institute of Standards and Technology are also capable of calibrating many types of portable readout units. Frequent field calibration checks can be accomplished on some portable readout units; for example, inclinometer probes can be checked by examining repeatability at the bottom immovable length of an installed inclinometer casing.

b. Retrievable components. Retrievable components are components that are mounted to a field terminal that can be removed for recalibration or replacement. For this reason, components should be mounted in the field terminal with shutoff valves or disconnect plugs in such a way as to allow for easy removal and replacement. Some components can be recalibrated without removal by using standard recalibration equipment located in or brought to the field terminal.

c. Embedded components. Embedded components are those that are buried or installed so that they are normally inaccessible. Many of these embedded components cannot be recalibrated because of their inaccessibility. For those that can be recalibrated, standard procedures should be developed for recalibrating the instrument types in question. To develop standard procedures, contact the manufacturers or other personnel with experience (see USCOLD 1993). Embedded components that can be recalibrated should be included in a routine recalibration schedule.

d. Calibration equipment. Calibration test equipment should be traceable to the National Institute of Standards and Technology. Test equipment used to recalibrate components of an instrumentation system must be maintained in good working order so that recalibration of the components can be made with accuracy.

e. Recalibration frequency. The recalibration frequency should depend on the type of instrument, the application of the instrument, and the operating environment. Some instruments require recalibration checks frequently during each day of readings, others require recalibration checks daily, weekly, monthly, or yearly. As a general rule, recalibrations should be made on a frequent schedule rather than an infrequent schedule. A more frequent schedule will allow data collection personnel to find any changes in calibration sooner, so that a minimum amount of erroneous data will be collected, processed, and reviewed before the instrument is recalibrated. A more frequent schedule could also aid in finding a malfunctioning instrument before it is damaged.

8-4. Maintenance During Service Life

a. Portable readout units. Portable readout units should be protected from mishandling, and be kept clean and dry. Attention should be given to all connection ports, O-rings, seals, accessory wires, and plug-in connectors. Protective plugs and caps should be in place when instruments are not being read, to protect the connectors and to keep them clean and dry. If protective plugs and caps are not provided by the manufacturer, they should be added to the instrument. Preferably, the plugs and caps should be attached to the units to avoid loss, and to make them easy for data collection personnel to use. All moving parts should be checked for tightness, damage or wear; worn or damaged parts should be replaced. Cables should be checked for damage to the outer coating and any cable markings. If there is moisture present in the readout unit, it should be removed by drying. Many units are supplied with desiccant that changes color when moisture is present. Batteries should be replaced as needed. Nickel-cadmium (nicad) batteries and lead-acid batteries are rechargeable batteries that require two different recharging procedures. The manufacturers' instructions for checking, maintaining, and recharging batteries should be followed.

b. Retrievable components. Retrievable components such as in-place inclinometers, electrical transducers, and thermistors can be installed as retrievable instruments so that they can be removed for maintenance and recalibration, and reinstalled or replaced. Protective barricades and protective enclosures should be maintained in good condition. Retrievable components, any wires, tubes, cables, and their enclosures should be kept clean, dry, and protected from rodents, vandals, and transient voltage surges. All plugs, caps, and covers should be maintained in good order and used properly. Maintenance inspections of the retrievable components and their protective structures should include inspections of wires, cables, tubes, etc. where they exit from the ground or structure. These areas are vulnerable to damage by accidents, weather, vandals, etc. When retrievable components are to be removed, observations of the existing installation and physical conditions should be noted. The instrument should be read before removal and after reinstallation. Any maintenance, recalibration, or replacement should be documented and communicated to the data management, reporting, and plotting personnel. Recommended follow-up checks and readings should be made to verify success of maintenance and to validate readings.

c. Embedded components. Embedded components are normally inaccessible and maintenance is not possible. However, there are various embedded components that require maintenance. Inclinometer casings, open standpipes, and relief wells can be inspected by downhole video cameras to determine if maintenance is required. Chemical analysis of water samples taken from these types of embedded components can be used to determine what maintenance treatment procedures are required for bacterial or chemical contamination.

d. Maintenance frequency. Maintenance should be preformed on a regular schedule and in accordance with procedures in the project O&M Manual or the manufacturer's instructions. Maintenance frequency should depend on the type of instrument, the application of the instrument, and the operating environment. A more frequent maintenance schedule may allow data collection personnel to find a malfunctioning instrument before it is damaged.

8-5. Instruments Requiring Specific Maintenance

Instruments that require more than the basic maintenance for portable readout units, retrievable components, or embedded components are discussed below.

a. Twin-tube hydraulic piezometers.

(1) To determine if maintenance is required for twin-tube hydraulic piezometers, the data collection personnel should compare current readings with previous readings to observe trends. The two gages can be compared to see if the pressures are equal. Under normal conditions the gages will indicate similar pressures. If they do not, flushing then rehabilitation is needed. The data collection personnel should observe the tubes and gages for bubbles and water clarity. Sediment or mineral deposits derived from the piezometer liquid may also be present. When flushing is performed, the data collection personnel should check to see if the discharged water contains gas, sediment, or mineral deposits.

(2) Maintenance tasks required for twin-tube hydraulic piezometers include flushing with de-aired liquid to clean the lines of any mineral deposits, and to remove accumulated gas bubbles from the tubing and manifold system (Dunnicliff 1988). When de-airing a piezometer, water under pressure may pass through the filter into the surrounding soil, causing excess pore water pressure in the soil that requires time to dissipate. In order to minimize or eliminate the buildup of pore water pressure in the soil when de-airing piezometers, a vacuum should be applied to one tube of the piezometer while de-aired water under a minimum pressure (calculated as shown by Dunnicliff 1988) sufficient to dislodge and move the air bubbles is applied to the other tube. Flushing procedures and pressure calculations are described in Dunnicliff (1988). The system should be checked frequently for

blockage and/or presence of gas. Sediment and mineral deposits derived from the liquid in the system must be flushed from the system if they are present. If deposits are allowed to accumulate in the system they will eventually plug the system and the instruments will be lost. Pressure gages should be checked periodically by comparing them with a master gage. Master gages and individual gages should be maintained and recalibrated and inaccurate or damaged gages should be replaced. For twin-tube hydraulic piezometers located in terminal structures above the frost line, protection from freezing is required, preferably by heating the structure. Maintenance of the heating equipment and control of moisture in the structure will be necessary.

b. Pneumatic piezometers. Data collection personnel should observe the instruments and readings to detect symptoms that may indicate that maintenance is needed. Unusual readings, sticking flow meters, evidence of moisture, leaking gas sounds, and valve malfunctioning are typical symptoms indicating that maintenance is needed. Pressure gages in pneumatic piezometer readout units require occasional calibration checks. Flowmeters will occasionally have to be cleaned to remove moisture or residue. The tubing may occasionally have to be flushed with purified, dry nitrogen gas to evaporate moisture from the tubing. O-rings and valves may have to be replaced if leaks are detected in the system.

c. Open standpipe piezometers. The hydrostatic time lag, frequently called response time, of each open standpipe piezometer should be established by performing a rising or falling head test at the time of installation. Test data may be converted to hydrostatic time lag for the piezometer by the method described in Chapter 2. The hydrostatic time lag for the piezometers should be reestablished periodically for a comparison with the initially established hydrostatic time lag. Such comparisons give an indication of the condition of the piezometer. Open-standpipe-type piezometers require periodic response tests to determine if the piezometer is effective or if maintenance is needed. In soils of low permeability, piezometer equalization can be obtained by adding or removing water in increments and observing the rate of rise or fall. The piezometers should be sounded periodically to determine if the tips contain sediments. If sediments are found, the piezometer should be flushed to remove sediment deposits from the bottom of the piezometer. Periodic disinfecting treatments may be required in piezometers that are located in environments that allow bacterial growth in the piezometers. Care should be taken when obtaining measurements to avoid introducing contaminants into the piezometer from the readout probe.

(1) In open standpipe piezometers where the water level rises above the frost line a nontoxic low-freezing-point fluid should be used to protect the piezometer from freezing. Maintenance may be required to replace the fluid so that it does not freeze and break the standpipe. Regardless of type of fluid used, the difference in specific gravities of the low-freezing-point fluid and the in situ pore water must be taken into account in adjusting the hydrostatic pressure shown by the piezometer.

(2) Observation wells are similar to open standpipe piezometers except they have no subsurface seals, therefore strata are vertically connected. Observation wells have limited use; however, their maintenance is basically the same as that for open standpipe piezometers.

d. Relief wells. Relief wells are outside the scope of this manual. Information on relief wells can be found in EM 1110-2-1914 and Driscoll (1986).

e. Probe extensometers. Probe extensometer readout devices must be kept clean and free of grit. Measuring tapes and cables should be inspected for kinks and kept dry. The riser pipes may require flushing to remove silt, corrosion, or plugging material.

f. Fixed borehole extensometers. The extensometer reference head must be kept clean of dust, grit, and moisture. The reference head may have to be reset if movement has occurred by following the manufacturer's instructions. Protection from direct sunlight or physical damage is required.

g. Inclinometers. The inclinometer probe, cable, and readout unit should be sent to the manufacturer for factory calibration and/or repair when either the check sums, the internal diagnostics, a malfunction, or unusual readings indicate that there is a problem with the instrument. Inclinometer casings may require occasional flushing to remove debris or sediment deposits from the bottom of the casing. Mechanical brushing can be used to remove biological or chemical residue or incrustation from the casing grooves. Inclinometer casings that have corroded, deteriorated, or deflected to such a state that readings can no longer be obtained, can sometimes be re-lined with a smaller inclinometer casing so that the inclinometer can still be used. Other types of instruments can also be installed in deteriorated inclinometer casings such as a slope extensometer or possibly a shear strip. These methods of instrumenting and re-using an existing inclinometer casing are normally much less expensive than drilling a new hole and installing a new inclinometer casing.

h. Seismic (strong motion) instruments. Maintenance of seismic (strong motion) instruments should be performed on a regular basis. Strong motion instrumentation is covered in ER 1110-2-103. A technician trained by the United States Geological Survey (USGS) or WES should check strong motion instruments on a periodic basis. The technician should check to see if the instrument has been tripped, check the operation of the instrument, and make sure the instrument has an ample amount of film. If it has been tripped, the exposed portion of the film should be removed for development and analysis.

i. Seepage measurement sevices. Routine maintenance is basically similar for most open-channel seepage measuring devices such as weirs, flumes, or seepage pipes. The channel and channel banks, or pool and pool banks near the device should be cleaned of weeds and debris. The sides, crest, outlets, and any measuring devices such as scales or staff gages should be cleaned of dirt, scum, mineral deposits, and bacterial or vegetation growth. The channel or pool should be cleaned of silt and sand deposits as they accumulate. If the cleaning has to be accomplished before the flow reading is taken, the flow reading should not be taken until the flow returns to its normal state.

(1) Weirs and flumes should be checked to make sure that they remain level and are at the same elevation as the zero reading on the staff gage. Weir notches or crests should be checked for nicks or dents that reduce their accuracy. Nicks or dents should be dressed or repaired if it can be done without changing the shape of the weir opening. If it cannot be repaired, the weir notch or crest should be replaced.

(2) Regular maintenance of flow or velocity meters includes keeping all moving parts clean, lubricated, free of corrosion, and in good working condition. Electrodes of electromagnetic instruments should be cleaned of any film buildup. The calibration of velocity meters should be checked frequently and recalibrated as needed.

8-6. Automation Equipment

The portable readout units, field terminals, and embedded components of an automated instrumentation system are basically the same as any instrumentation system and should receive the same care and maintenance. Automation equipment is discussed in Chapter 5. Automated instrumentation systems, communications systems, electronic equipment, dataloggers, data controllers, and computers contain sophisticated electronic components and will usually require the care of experienced electronics personnel.